

THE SOIL FAUNA AND AGRICULTURE:
PAST FINDINGS AND FUTURE PRIORITIES

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ПОЧВЕННАЯ ФАУНА И СЕЛЬСКОЕ ХОЗЯЙСТВО: ПОСЛЕДНИЕ ДОСТИЖЕНИЯ И ПЕРСПЕКТИВЫ
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Introduction

Agriculture is defined as the science or practice of cultivating the soil and rearing animals, and cultivation as the preparation, tillage and use of soil to produce crops. Because definitions aim to clarify and simplify meaning, they often perpetuate destructive myths that are harder to change than the definitions that incorporate them. The above definitions, for example, paint a picture of a linear agriculture with a "black box", the soil, in the middle. The farmer stirs up the soil with a tool, sows seeds and harvests the plants that mysteriously grow. At first the system was thought to be limited by people, land, seeds and tools. More recently, synthesized fertilizers and pesticides have been added to the equation. These and other developments have led to an agriculture that is characterized by large parcels of land being kept bare for most of the year, often only one crop species being grown year after year, and production being maintained through a heavy reliance on imported seeds, energy (as fuel for equipment), fertilizers and pesticides, etc. The outcome has been a loss of independence, increased environmental stress and an outflow of capital from the system in terms of crop cultivars, soil and nutrients, water, natural controls of pests, and other beneficial organisms.

Studies of the relationships between soil fauna and agriculture have been conducted within such systems. They comprise three types of studies: 1) of pest species and their control, 2) of beneficial species and their effects and 3) of the effects of agricultural practices on soil animals. Because of the difficulties of studying organisms in a stratified opaque medium that is complex in terms of its physical, chemical and biological parameters, and that varies in time and space, progress in all of these areas have been limited.

Some general statements, however, can be made. Useful reviews are provided in /22,23,11,29,39,7,18/. As most of the following statements are of a general nature or are based upon the general soil-fauna literature and/or personal observation they are not supported by specific references. References are, however, given where useful reviews or "landmark" papers are known to exist, or where particular points may need to be stressed.

Soil Pests

1. Pests occurring within the soil are at least as significant, in terms of economic damage, as are those found above the ground.
2. Pesticides, because of difficulties of distribution in soil, adsorption and decomposition, have provided less effective control in soil than above ground.
3. The biology and ecology of most soil pests is poorly understood, and relatively few biological controls have been exploited.
4. The use of cultural methods (crop rotation, use of intercrops, timing of operations, soil and habitat management) and resistant crop varieties, if available, are essential for the control of soil-inhabiting pests.

Effects of Beneficial Soil Animals

1. All soil animals (even pest species) have some beneficial effects on soil structure and fertility.
2. Although their direct effects on processes such as soil formation and organic-matter decomposition are small in comparison with those of micro-organisms, their indirect and catalytic effects are substantial and essential. These include the improvement of food and space conditions for both micro-organisms, and higher plants, selective cropping and transportation of micro-organisms, aeration, drainage, biological control of pests and soil mixing. Generally, their role should be seen as one of "regulation" rather than the simple acceleration of soil processes, which is a common misconception. For discussions, see /27,40,20,5,25,2,26,31,34/.
3. Most studies of the contribution of soil animals have failed to deal with the soil system as a functional whole. Rather, they have focused on isolated groups and processes. Consequently our views of how the soil functions is still fragmentary.
4. Few attempts have been made to introduce and manage beneficial soil fauna /10/. Developments in this area will eventually lead, together with parallel developments in other areas, to the redesign of food-producing systems and to changes in our approach to soil management.

Effects of Agricultural Practices

1. Dominant agricultural practices (tillage, clean cultivation, monoculture, row crops, use of pesticides and certain synthetic fertilizers) simplify the soil community and reduce the beneficial contributions of soil animals /11,12,4/. Manures and most fertilizers generally increase numbers and species of soil animals /28/.
2. Although numerous studies have been carried out on these effects they have not led to any changes in agricultural practices - the beneficial soil

fauna remains a largely unknown and untapped resource within the food production system.

3. Preliminary studies have indicated the value of using the presence and population density of certain soil animals as indicators of soil conditions /21/.

4. The growing concern with soil degradation and interest in minimum tillage and other ecological approaches to agriculture are causing some attention to be focussed on the soil fauna /36,6,37/. The questions that are being asked provide soil ecologists with an important opportunity to make practical contributions to the design of sustainable food-production systems.

Sustainable Agriculture

As responsible scientists we have an important role to play in the evolution of a sustainable life-style for our species. Because of its increasing dependence on distant resources, both non-renewable and renewable, and its heavy environmental impact, modern agriculture is clearly not indefinitely sustainable in its present form.

Systems of agriculture that overtly have increased "productivity" so satisfy markets (in some cultures manipulated through advertising), "profit" and "power" (whether individual, corporate or governmental) as their primary goals, can never be sustainable and will always lead to the degradation of humanity and the Earth. This is because the "goals" mentioned know no limits. They are exhausting of resources and unresponsive to their harmful side-effects. What may be argued for is a greater social conscience among scientists and a translation of that conscience into research that is relevant to food-production systems that have goals such as nourishment, fulfilment, flexibility, evolution and sustainability /16,19,17/. One may also appeal to soil biologists and ecologists to speak out on these issues, and to broaden their areas of interest to include the food-production system as a whole and its sustained operation over the long-term.

Let us now look at what a sustainable food-production system might entail and what contributions soil biologists can make towards its development and implementation.

In terms of material flows, a sustainable agriculture may be viewed as a production-consumption-recycle system. Most of the recycle process takes place within the soil in the form of organic matter decomposition. For sustainability to be achieved, input for decomposition must meet certain quantitative and qualitative criteria, e.g., comprise a diverse range of substrates containing adequate amounts of major, minor and trace elements that, together with those from the earth's crust and the atmosphere, are capable of supporting plant growth. Substrates must also meet certain criteria in respect of time, space and freedom from toxins. These criteria are more likely to be met in a "multistorey" polyculture that includes soil and ecosystem maintenance, as well as food producing, plants and animals, than in a unistorey row-crop monoculture /30,1,38/. The agricultural task is the design and management of such systems and the task of soil zoology is to describe the animals and processes that take place in the soil and, with others, to develop methods of soil management that can enhance the beneficial contributions of the soil fauna.

The approach to problems in such systems will probably differ radically in the future from that employed today. Currently, agricultural problems usually receive attention only when their short-term economic consequences justify the required expenditures. Solutions tend to be confined to disciplines rather than being multidisciplinary: entomologists dealing with insects, nematologists with nematodes, and so on.

An alternative approach recognizes that the causes of problems often lie outside of the discipline concerned with their subject, and that prevention is usually less costly than cure. Such an approach might more effectively channel the efforts and resources that currently are used to attack directly the problems besetting a less easily defined, multifaceted agro-ecosystem maintenance function. Thus, by working to optimize the functioning of the agro-ecosystem as a whole, problems within its parts would be minimized. Those that arise would be taken as indicators of malfunction, and efforts would be made to correct such a malfunction. To be effective with this approach farmers would need to be more knowledgeable and "closer" to the system, as well as being supported more by society. Sociologically the process may be viewed as one of integration (of the human species into the rest of the biosphere), balance (the maintenance of a sustainable relationship with the supporting environment) and feedback (paying close attention to the outcomes of our actions, recognizing their meaning and responding accordingly). Thus, attention is shifted from problem solving to system maintenance, the incidence of problems declining as systems approach optimal states. Such problems as do arise would be solved largely by removing the causes and strengthening the natural processes that normally prevent such problems from reaching crisis proportions /18/.

Indicators of Agro-Ecosystem Distress

Recognition of undesirable processes often involves the identification of environmental stressors and the detection and measurement of their effects.

Because of the widespread and diverse nature of environmental stressors, and because of the complex nature of their interactions, there is a need to find ways in which to detect and measure their combined effects in a general way. Under the influence of recognition of a "biological distress syndrome" in mammals /35/, it has been proposed /33/ that we recognize a parallel "ecosystem distress syndrome" within environments. This concept is based on two important assumptions: 1) that different stressors give rise to certain similar symptoms (cf. Selye's "general adaptation syndrome"); and 2) that there are common indicators of distress that can be used in widely different ecosystems that are subject to different stressors.

The situation in mammals, however, is much more complicated than it has been indicated in /35/. In /32/ five levels were used to describe recognizable points along a continuum from healthy to severe illness within affected humans. One valuable insight from his observations is that, at different times, the same or similar symptoms present themselves in "up" (e.g., hyperactive) and "down" (e.g., depressed) states. While these are both recognized as being undesirable at the developed end of the spectrum, the "up" con-

dition (active, responsive, enthusiastic, ambitious, witty), during the early stages of development, may easily be regarded as desirable, its connection with the "down" condition (stuffy nose, occasional coughing and sneezing, skin disorders, gas, diarrhoea, constipation, frequent urination and various eye and ear symptoms) not being recognized.

There may well be parallels to these observations with respect to the soil ecosystem /15/. Thus, certain management practices may at first appear to be beneficial when measured in terms of their short-term influences on productivity. The negative effects of such practices are either hidden or not taken seriously until they reach crisis proportions, when it may be too late to correct the situation.

The following indicators of environmental distress, identified in /33/ for the Great Lakes Ecosystem, are equally applicable to soil ecosystems: 1) imbalance in nutrient concentrations (loss of some, accumulation of others); 2) reduced species diversity; 3) replacement of longer lived by shorter lived species (adapted to transitory novel environments); 4) replacement of larger by smaller life forms; 5) decline in biomass of macrofauna; 6) increase in amplitude of population fluctuations by key species.

Some of these were recently recognized /3/ in the study of the effects of various agricultural practices on soil mesofauna.

One problem with these indicators is that they provide only an after-the-fact indication of distress. This limitation similarly applies to many specific indicators of environmental contamination, such as the accumulation of toxins up the food chain, and the incidence of reproductive failure among top-level predators /33/.

In addition to these indicators, we urgently need others that are capable of providing us with an early warning of deteriorating conditions. For this, in /33/ it has been proposed that we identify "indicator-integrator" organisms, i.e., species that are representative of their communities, that are able to survive only in relatively unstressed ecosystems, and that are sensitive to a broad range of stressors.

Among soil invertebrates, predators within the air spaces and water film and highly mobile burrowers would seem likely candidates for this role. Some years ago, it has already been stressed /21/ the value of using predatory soil mites and ants /14/ as indicators. Predatory nematodes would probably serve a similar function within the water film. In fact, all soil animals are indicators of soil conditions. The problem lies in the interpretation of the information available. Predators are particularly valued because their presence, population density, behaviour and body composition can provide, in a sense, a summation of most of the information provided separately by the organisms lower down in the food web. Among the non-predators, earthworms are already widely regarded by farmers as indicators of soil health, and have been successfully used as indicators of soil pollution by pesticides and industrial chemicals /8,9/; in /13,24/ it has been proposed using soil fauna as indicators of soil type. The person with the greatest need for this "indicator information" is the farmer. Research workers should bear this in mind.

While it is essential that more work be done in this area, experience

from other fields is not encouraging with respect to the ability of such studies, on their own, to bring about appropriate changes in agricultural practices. While most human populations are willing to support studies of the side-effects of their behaviour, it is rare to find changes in behaviour resulting from such studies! It may be readily observed that most people want to hear only truths that validate their existing ways of life, that do not cause them to feel guilty, and that do not suggest that they should change their behaviour. It is often implied that, as scientists, we are more objective and more willing to be open to truths that disturb, but this is a very moot point. It is more credible that most of us conduct our science (and our lives), just as non-scientists conduct their lives, within a territory determined by our vulnerability to those truths that are likely to distress us. This implies that, by increasing our vulnerability, we are likely to improve our science. This involves being more open towards our colleagues, towards those in other disciplines, towards non-scientists and, in a somewhat different sense towards the subjects of our research.

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Секция 2

БИОТИЧЕСКИЕ СВЯЗИ ПОЧВЕННЫХ БЕСПОЗВОНОЧНЫХ

Section 2

BIOTIC RELATIONS OF SOIL INVERTEBRATES